Supplementary material to the article:

Revision of Eocene electric rays (Torpediniformes, Batomorphii) from the Bolca Konservat-Lagerstätte, Italy, reveals the first fossil embryo in situ in marine batoids and provides new insights into the origin of trophic novelties in coral reef fishes

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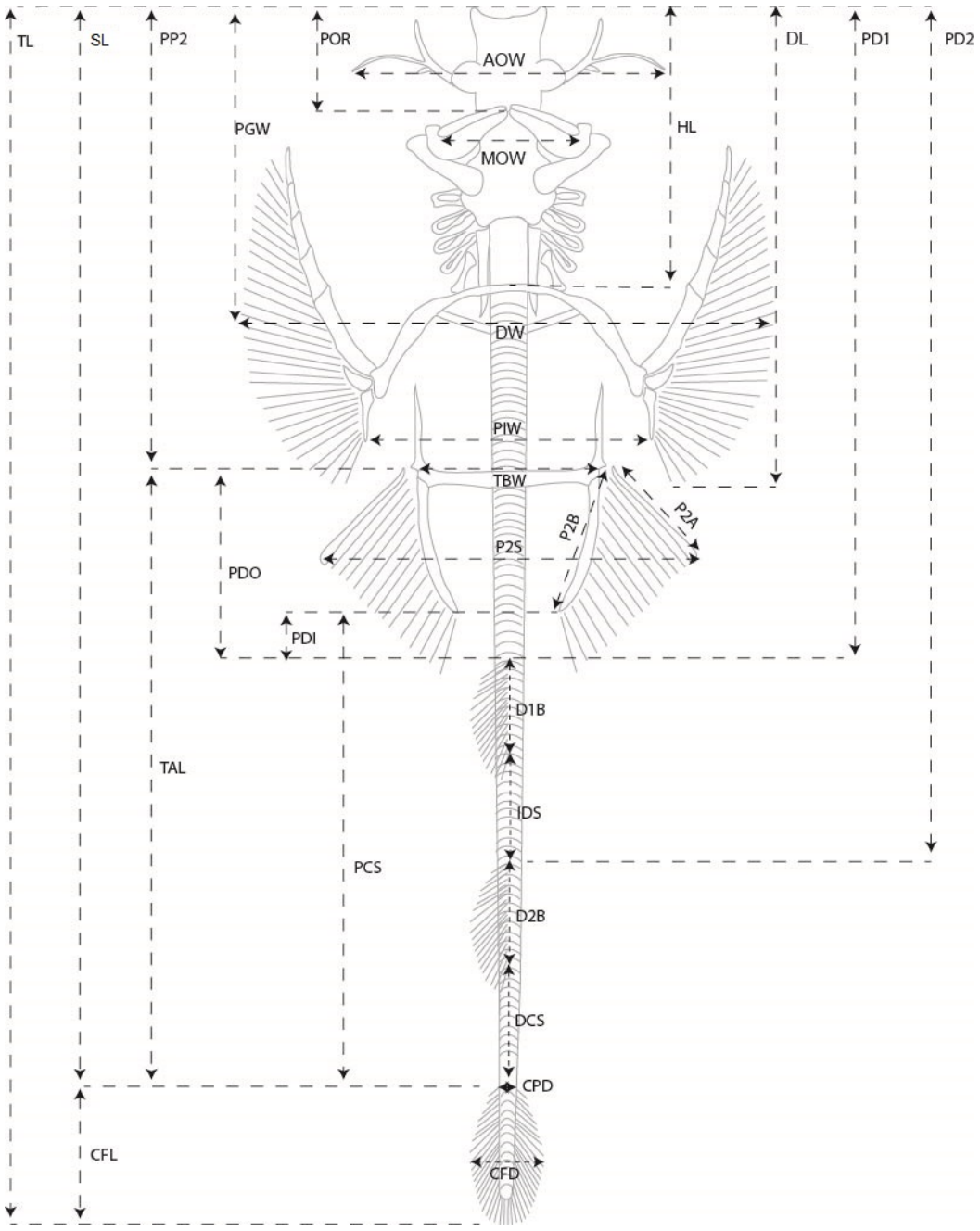
Appendix 1: Electric ray specimens examined.

Benthobatis marcida Bean and Weed, 1909: MCZ 41171 (x10); ZMH 119661; ZMH 119660; ZMH 119863.
Diplobatis picta Palmer, 1950: MCZ 40377 (x3); ZMH 123096.
Discopyge tschudii Heckel, in Tschudi, 1844: ZMH 104818 (2); CJU (x2).
Heteronarce mollis (Lloyd, 1907): ZMH 113459.
Hypnos subnigrum (Duméril, 1852): MCZ S985; ZMB 33928; ZMH 10427.
Narcine brasiliensis (von Olfers, 1831): AMNH 218276; AMNH 90769: AMNH 92321.a; AMNH95343; TNHC 18512; ZMB 11889.
Narcine rierai (Lloris and Rucabado, 1991): ZMH 113381.
Narcine sp.: ZMB 33929; ZMB 33930; ZMB 33931.
Narcine tasmaniensis Richardson, 1841: AMNH 95343.
Narke dipterygia (Bloch and Schneider, 1801): ZMB 33911.
Narke japonica (Temminck and Schlegel, 1850): SIO 85–138i.
Potamotrygon tigrina Carvalho *et al*. 2011: IUWP 7361
Temera hardwickii Gray, 1831: NHMUK 1984.1.18.6; NHMUK 1887.4.16.14.
†*Titanonarke megapterygia* n. sp.: MCSNV IG.135576.
†*Titanonarke molini* (Jaekel, 1894): MGP-PD 26275/6; MCSNV IG.VR.91359; MCSNV IG.VR.67290; MCSNV IG.91128/9; MCSNV IG.135581.
Torpedo cf. *marmorata* Risso, 1810: IUWP tbzs_10; IUWP tbzs _11; IUWP tbzs _12
Torpedo nobiliana Bonaparte, 1835: ESB_200608_23_001; ESB_200707_322_001; ESB_200707_310_001; ESB_tn200707_159.
Torpedo torpedo (Linnaeus, 1758): MCZ_Glass_156-178; MCZ_Glass_143-167; MCZ_Glass_203-257; ZMB_Glass_1295-32F; ZMB_Glass_1333-70F; ZMB_Glass_1371-03F; ZMB_Glass_14a; ZMB_Glass_382-407F; ZMB_Glass_408-459F; ZMB_Glass_460-529F; ZMB_Glass_501-28or; ZMB_ Glass_529-49or; ZMB_Glass_5; ZMB 33932 (34); ZMB 33933.
Typhlonarke tarakea Phillipps, 1929: ZMH 119562 (x2); SIO 64-288.

Appendix 2. The holotype of †*Titanonarke molini* (MGP-PD 26275/6, in part and counterpart) under UV light. The pigment used to preserve the specimen reflects orange/yellow light. Different kinds of grout (in light and dark blue) were used to fill the gaps or to join the pieces of slab.

Appendix 3. Simplified anatomical scheme and abbreviation used for the morphometric measurements. Terminology mostly follows Compagno & Heemstra (2007). Abbreviations: AOW, antorbital cartilage width; CFL, caudal-fin length; CFD, caudal-fin depth; CLO, clasper length (not represented); CPD, caudal peduncle depth; D1B, first dorsal-fin base length; D2B, second dorsal-fin base length; DCS, dorsal caudal space; DL, disc length; DW, disc width; HL, head length; IDS, interdorsal space; MOW, mouth width; P2A, pelvic-fin anterior margin length; P2B, pelvic-fin base length; P2S, pelvic-fin span; PCS, space from pelvic-fin insertion to the caudal-fin origin; PD1, predorsal distance up to the first dorsal fin; PD2, predorsal distance up to the second dorsal fin; PDI, pelvic-fin insertion to first dorsal-fin origin; PDO, pelvic-fin origin to first dorsal-fin origin; PGW, snout tip to the level of the greatest disc width; PIW, body width at pectoral-fin insertions; POR, preoral length; PP2, prepelvic length; SL, standard length; TAL, tail length; TBW, tail base at pelvic-fin origin; TL, total length.



Appendix 4. List of morphological characters used for the phylogenetic analysis. Data are based on Claeson (2014) to which we added and discussed new characters from 66 to 72. Some characters from Claeson (2014) have been re-checked and corrected (see **Remarks** for these characters below).

1. Pectoral electric organs: (0) absent; (1) present. CI 1.00, HI 0.0, RI 1.0.
2. Skin texture: (0) scales or thorns present; (1) smooth, naked skin. CI 1.00, HI 0.00, RI 1.00
3. Eyeball: (0) uncovered eye, flush with dorsal surface; (1) uncovered eye, protrudes above dorsal surface; (2) 'eyelid' or partial integumentary covering; (3) covered by integument. CI 0.50, HI 0.50, RI 0.50.
4. Spiracle relationship to eye: (0) continuous with eye; (1) narrow bridge between spiracle and eye; (2) no shared rim, widely separated. CI 0.67, HI 0.33, RI 0.75.
5. Spiracle rim shape: (0) laterally elongate; (1) anteroposteriorly elongate. CI 0.50, HI 0.50, RI 0.00.
6. Spiracular papillae: (0) absent; (1) present. CI 0.33, HI 0.67, RI 0.00.
7. Spiracular papillae: (0) button-like papillae; (1) finger-like papillae. CI 1.00, HI 0.00, RI 1.00.
8. Spiracular rim: (0) flush with dorsal integument; (1) rigid and elevated above integument; (2) depressed below integument. CI 0.67, HI 0.33, RI 0.50.
9. Anterior nasoral turret: (0) flush with body, not projecting; (1) projects ventrally. CI 1.00, HI 0.00, RI 1.00.
10. Circumnarial folds: (0) present; (1) absent. CI 1.00, HI 0.00, RI 1.00.
11. Circumnarial fold shape: (0) semi-circle; (1) semi-oval; (2) full circle. CI 0.50, HI 0.50, RI 0.33.
12. Nostrils: (0) incompletely divided; (1) completely divided. CI 0.50, HI 0.50, RI 0.00.
13. Nasal curtain: (0) present; (1) absent. CI 1.00, HI 0.00, RI 1.00.
14. Medial groove on nasal curtain: (0) absent; (1) present. CI 0.33, HI 0.67, RI 0.00.
15. Sensory pores of ventral lateral line system on nasal curtain: (0) inconspicuous; (1) sparse; (2) dense. CI 0.67, HI 0.33, RI 0.75.
16. Caudal margin of nasal curtain: (0) arched margin; (1) straight margin; (2) medial projection; (3) v-shaped notch. CI 1.00, HI 0.00, RI 1.00.
17. Extent of nasal curtain when mouth is closed: (0) ends anterior to upper lip; (1) covers upper lip and dentition. CI 1.00, HI 0.00, RI 1.00.
18. Lateral tabs of nasal curtain: (0) absent; (1) present. CI 0.50, HI 0.50, RI 0.00.
19. Divided lower lip: (0) absent, lower tooth row does not divide lip; (1) present, lower tooth row divides lip. CI 0.50, HI 0.50, RI 0.75.
20. Mental groove: (0) absent; (1) present. CI 1.00, HI 0.00, RI 1.00.

21. Labial cartilage: (0) absent; (1) small, combined are less than the length of the Meckel's cartilage; (2) large, combined are greater than the length of the Meckel's cartilage. CI 1.00, HI 0.00, RI 1.00.

22. Jaw shape: (0) short and stout jaw cartilages; (1) long, slender, flexible jaw cartilages. CI 1.00, HI 0.00, RI 1.00.

23. Relative size of mandibular arch cartilages in dorsoventral view: (0) approach same size; (1) palatoquadrate labio-lingually compressed (narrower than Meckel's cartilage) and tapers toward symphysis. CI 0.50, HI 0.50, RI 0.83.

24. Hyomandibula: (0) narrow and elongate; (1) medially expanded and plate-like; (2) expanded only at the oto-occipital articulation. CI 1.00, HI 0.00, RI 1.00.

25. Number of dorsal fins: (0) zero or absent; (1) one fin; (2) two fins. CI 1.00, HI 0.00, RI 1.00.

26. Precaudal tail: (0) long tail; (1) short and stout precaudal tail; (2) inconspicuous. CI 0.67, HI 0.33, RI 0.75.

27. Lateral tail folds: (0) inconspicuous; (1) narrow; (2) broad. CI 0.33, HI 0.67, RI 0.20.

28. Pelvic fin lobes in females: (0) free-hanging with medial margin of pelvic fin lobes free of precaudal tail; (1) medial margin of pelvic fin lobes attached to precaudal tail; (2) medial margin of pelvic fin lobes join together to form 'apron'. CI 0.50, HI 0.50, RI 0.50.

29. Pelvic fin (0) single lobed (1) double lobed. CI 1.00, HI 0.00, RI 1.00.

30. Length of clasper: (0) extends past posterior tips of pelvic fin lobes; (1) does not extend past posterior tips of pelvic fin lobes. CI 0.33, HI 0.67, RI 0.00.

31. Iliac process length: (0) short and stout; (1) long and slender; (2) inconspicuous. CI 0.50, HI 0.50, RI 0.33.

32. Iliac process curvature: (0) curved; (1) straight. CI 0.33, HI 0.67, RI 0.50.

33. Prepelvic process length: (0) short; (1) long, i.e., greater than 2x the caudorostral depth of the ischiopubic bar. CI 1.00, HI 0.00, RI 1.00.

34. Prepelvic process shape: (0) pointed; (1) flat and tab-like; (2) wider towards tip than along shaft. CI 0.40, HI 0.60, RI 0.57. **Remarks:** we changed the states of this character for *Benthobatis* and *Discopyge* from (0) to (2). In fact, the prepelvic process has been described and figured wider toward tip than along the shaft also for *Benthobatis* (Rincon *et al*. 2001, fig. 8), *Diplobatis* and *Discopyge* (Fechhelm & McEachran 1984, figs 7 and 16), other than for *Narcine* (Claeson 2014). However, although the state (2) is unique in Narcinidae among torpediniforms, it was not detected as synapomorphy of the group by TNT.

35. Suprascapular antimere fusion: (0) fused without visible suture; (1) fused with visible suture. CI 1.00, HI 0.00, RI 1.00.

36. Suprascapulae-vertebral association: (0) not articulated or fused to one another; (1) articulates with vertebrae posterior to the synarcual; (2) fused with the synarcual. CI 1.00, HI 0.00, RI 1.00. **Remarks:** the state for the suprascapulae-vertebral association for all torpediniforms was changed from (2) fused with the synarcual, to (0) not articulated or fused to one another, according to the interpretation of Claeson (2014); vice versa, the state for *Raja* was changed from (0) to (2).
37. Suprascapular projection: (0) lateral; (1) ventrolateral. CI 1.00, HI 0.00, RI 1.00.
38. Shape of suprascapulae: (0) straight; (1) anteriorly bowed. CI 0.33, HI 0.67, RI 0.50.
39. Length of suprascapula: (0) suprascapular antimere is longer than scapular process; (1) suprascapular antimere is equal to scapular process; (2) suprascapular antimere is shorter than scapular process. CI 0.67, HI 0.33, RI 0.50.
40. Suprascapula-scapulocoracoid articulation: (0) unforked; (1) interdigitating fork; (2) tight, socket articulation. CI 1.00, HI 0.00, RI 1.00.
41. Anterior extension of mesopterygium: (0) shorter than propterygium and metapterygium; (1) shorter than propterygium but longer than metapterygium; (2) longer than propterygium and metapterygium. CI 1.00, HI 0.00, RI 1.00.
42. Antorbital cartilage: (0) no branching; (1) bifurcating; (2) broadly branching. **Remarks:** the state of the antorbital cartilage for *Discopyge* was changed from (1) bifurcating, to (2) broadly branching following Fechhelm & McEachran (1984). CI 0.50, HI 0.50, RI 0.60.
43. Antorbital-nasal capsule articulation: (0) antorbitals articulate on lateral aspect of nasal capsules; (1) antorbitals articulate on anterior aspect of nasal capsules. CI 1.00, HI 0.00, RI 1.00.
44. Rostral fontanelle: (0) absent; (1) present. CI 1.00, HI 0.00, RI 1.00.
45. Frontoparietal fontanelle: (0) present; (1) absent. CI 0.33, HI 0.67, RI 0.33. **Remarks:** the states for the frontoparietal fontanelle have been recoded as (0) present, and (1) absent, instead of (0) absent, and (1) present in the Supplementary Material of Claeson (2014), since its absence was considered the derived condition among the Torpediniformes (Claeson 2014).
46. Internasal plate: (0) flat and wide (1) flat and narrow; (2) small or inconspicuous. CI 0.50, HI 0.50, RI 0.67.
47. Nasal capsules in dorsoventral view: (0) project anteriorly; (1) project laterally; (2) compressed laterally. CI 0.67, HI 0.33, RI 0.00.
48. Nasal capsules in lateral view: (0) flush with basal plate; (1) project ventrally. CI 1.00, HI 0.00, RI 1.00.
49. Median rostral cartilage: (0) trough-shaped and expanded; (1) slender; (2) inconspicuous or absent. CI 0.50, HI 0.50, RI 0.60.
50. Lateral rostral cartilages: (0) absent; (1) articulated with nasal capsule; (2) continuous with chondrocranium. CI 0.50, HI 0.50, RI 0.50.

51. Hypobranchial plate: (0) unfused hypobranchials; (1) posterior hypobranchial cartilages fused. CI 0.25, HI 0.75, RI 0.40.
52. Size of basibranchial copula: (0) large; (1) small. CI 1.00, HI 0.00, RI 1.00.
53. Shape of basibranchial copula: (0) inverted triangle (wide anteriorly, narrow posteriorly); (1) rounded with a small caudal point/tab; (2) heart-shaped (anterior margin is depressed medially, posterior margin tapers); (3) tack- or t-shaped. CI 1.00, HI 0.00, RI 1.00.
54. Dorsal marginal clasper cartilage: (0) lacks distomedial extension/medial flange; (1) possesses distomedial extension/medial flange. CI 1.00, HI 0.00, RI 1.00.
55. Ligamentous sling on Meckel's cartilage: (0) absent; (1) present. CI 1.00, HI 0.00, RI 1.00.
56. Coracobranchialis: (0) consists of three to five components; (1) single component. CI 1.00, HI 0.00, RI 1.00.
57. Coracohyomandibularis: (0) single origin; (1) separate origins on the fascia supporting the insertion of the coracoarcualis and on pericardial membrane. CI 1.00, HI 0.00, RI 1.00.
58. Dorsal rim of anterior neural canal opening (synarcual mouth): (0) anterior to occipital cotyle; (1) posterior to occipital cotyle. CI 0.50, HI 0.50, RI 0.80.
59. Ventral rim of the anterior neural canal opening (synarcual lip): (0) smooth single curve; (1) notched or bifurcated. CI 0.20, HI 0.80, RI 0.20.
60. Synarcual-occipital articulation: (0) lip rests in foramen magnum; (1) lip rests in concavity beneath foramen magnum; (2) lip rests in paired concavity beneath foramen magnum. CI 1.00, HI 0.00, RI 1.00.
61. Lateral stay: (0) present; (1) inconspicuous. CI 1.00, HI 0.00, RI 1.00.
62. Position of lateral stay: (0) midway along length of synarcual; (1) anterior one-third of length; (2) posterior one-third of length. CI 0.40, HI 0.60, RI 0.40.
63. Distal end of lateral stays: (0) tab; (1) point; (2) wide. CI 1.00, HI 0.00, RI 1.00.
64. Anterior margin on lateral stay: (0) approximately perpendicular to axis of synarcual; (1) acute angle to axis; (2) obtuse angle to axis. CI 0.50, HI 0.50, RI 0.50.
65. Position of anteriormost free vertebral centrum: (0) surrounded by posterior flanges of synarcual; (1) posterior to synarcual. CI 0.50, HI 0.50, RI 0.00.

Characters 66 to 70 pertain to the tooth morphology, already detected for torpediniforms and outgroups by Herman *et al*. (1995, 1997, 2002) and Compagno & Heemstra (2007), but not included in the analysis of Claeson (2014).

66. Number of tooth cusps: (0) one; (1) more than one; (2) cusp absent. CI 0.67, HI 0.33, RI 0.50.
Remarks: *Raja* and most of torpediniforms (including †*Titanonarke* and †*Eotorpedo*, see also

Herman 1995, 2002; Carvalho 2010; Cappetta 2012) have only one cusp. *Hypnos* is the only torpediniform having multicuspidate teeth (Herman *et al*. 2002). *Pristis*, *Platyrhinoidis* and *Temera* have no cusp (Herman *et al*. 1995, 1997, 2002). Polarity: the derived condition is the absence of cusp or the presence of multicuspidate teeth.

67. Shape of the cusp: (0) narrow and high; (1) broad and low. CI 1.00, HI 0.00, RI 1.00. **Remarks:** For *Hypnos* we consider the central one. *Raja* and most torpediniforms (including †*Titanonarke* and †*Eotorpedo*) have narrow and high cusp (Herman *et al*. 1995, 2002; Carvalho 2010; Cappetta 2012). *Electrolux*, *Heteronarce*, *Narke* and *Typhlonarke* have broad and low cusp (Herman *et al*. 2002; Compagno & Heemstra 2007). Polarity: the derived condition is (1).

68. Length of the cusp: (0) longer than cutting edge length; (1) less than half the cutting edge length; (2) as long as cutting edge. CI 0.67, HI 0.33, RI 0.75. **Remarks:** *Raja*, *Hypnos*, *Torpedo* and †*Eotorpedo* have cusp longer than cutting edges (Herman *et al*. 1995, 2002; Cappetta 2012). *Bentobatis*, *Narcine*, *Electrolux*, *Heteronarce*, *Narke*, †*Titanonarke* have a main cusp that is less than half the cutting edge length (Herman *et al*. 2002; Compagno & Heemstra 2007). *Discopyge* and *Diplobatis* have a main cusp that is as long as cutting edges, whereas *Typhlonarke* shows a polymorphic condition (1/2) (Herman *et al*. 2002). Polarity: the derived condition is (1) and (2).

69. Mesial/distal cutting edge shape: (0) curved upward (arched); (1) straight; (2) blade-like. CI 1.00, HI 0.00, RI 1.00. **Remarks:** *Raja*, *Hypnos*, *Torpedo*, †*Eotorpedo*, *Bentobatis*, *Electrolux*, *Heteronarce*, *Typhlonarke* have been described having mesial and distal cutting edges curved upward (Herman *et al*. 1995, 2002; Compagno & Heemstra 2007; Cappetta 2012). *Narke* has straight cutting edges, whereas *Discopyge*, *Narcine*, *Diplobatis* (Herman *et al*. 2002) and †*Titanonarke* have blade-like cutting edges. Polarity: the derived conditions are (1) and (2).

70. Root shape: (0) high and narrow; (1) low and narrow; (2) low and broad. CI 0.67, HI 0.33, RI 0.75. **Remarks:** Outgroups, *Bentobatis*, *Discopyge*, *Narcine*, *Diplobatis*, *Heteronarce*, *Narke* and †*Titanonarke* have high and narrow root (Herman *et al*. 1995, 1997, 2002; Compagno & Heemstra 2007). *Electrolux*, *Temera* and *Typhlonarke* have low and narrow root, whereas *Hypnos*, *Torpedo* and †*Eotorpedo* possess low and broad root (Herman *et al.* 2002; Cappetta 2012). Polarity: the derived conditions are (1) and (2).

The characters 70 and 71 pertain to new morphological and meristic features detected in the new analysis of living and fossil specimens. Being the extinct torpedinoid †*Eotorpedo* only represented by isolated teeth (see Carvalho 2010; Cappetta 2012) it was not possible to code these characters for this genus.

71. Number of ribs: (0) high, more than 10 pairs; (1) reduced, up to 10 pairs. CI 1.00, HI 0.00, RI 1.00. **Remarks:** the analysis of the meristic features for recent and fossil specimens recovered a common character for *Benthobatis*, *Diplobatis*, *Discopyge*, *Narcine* and †*Titanonarke*, that supports the monophyly of the family Narcinidae. In fact the representatives of this family show up to ten pairs of ribs, which is the lowest count among torpediniforms, usually having more than ten rib pairs (see also Table 2 and related references). Outgroups, torpedinids, and narkids have a higher number of rib pairs, whereas narcinids have a low number of rib pairs. Data from new observations and from Carvalho *et al*. (1999, 2002), Compagno & Heemstra (2007). Polarity: the derived condition is the low number of rib pairs.

72. Rostral cartilage connected to the antorbital cartilage through lateral appendices of the rostral cartilage: (0) absent; (1) present. CI 1.00, HI 0.00, RI 1.00. **Remarks:** the connection of the rostral cartilage to the antorbital cartilage through small lateral projections (= rostral appendices of Holmgren 1941; lateral rostral cartilage of Carvalho 1999) was also detected for *Diplobatis* (Fechhelm & McEachran 1984, fig. 5), *Benthobatis* (Rincon *et al*. 2001, fig. 7) and all narcinids in general (Fechhelm & McEachran 1984, fig. 16; Carvalho 1999, 2010). Rostral appendices are also present in *Torpedo*, *Hypnos*, *Narke* and *Raja* (see also Holmgren 1941) but they are not directly connected to the antorbital cartilages. Being the connection of the rostral cartilage to the antorbital cartilage through lateral appendices unique in narcinids among torpediniforms and outgroups (see also Fechhelm & McEachran 1984; Carvalho 1999, 2010), it supports the monophyletic status of the Narcinidae. *Benthobatis*, *Diplobatis*, *Discopyge*, *Narcine* and possibly †*Titanonarke* possess this character. Rostral cartilage connected to the antorbital cartilage through lateral appendices of the rostral cartilage is absent in outgroups, torpedinids and narkids. Polarity: the presence of lateral appendices is considered derived.

Appendix 5. Data matrix used in the phylogenetic analysis.

Raja	000000-0000000[01]00000000020000000000020000000000[10]00000000000000000000000000
Pristis	000210-001-01-----000000200000????0?000100001000000000?000010021202---000
Platyrhinoidis	002200-000201-----00000020000000000100210200001000000000000001000002---000
Hypnos	11101110002000010000001012200002-11?000200010122021001?000010000101000200
Torpedo	11020[01][01]000200001000001022110000110100120001012102200100000120100000000200
Benthobatis	113000-0002000110010101[02]200100011210000001010111000001????110020210010011
Diplobatis	112101000021002100101010201101011210010001010111001 01????110000200022011
Discopyge	112100-000210012001010102002001012100100220101110000 1????100020200022011
Narcine	112100-000[02]0001[21]00101010202000101210 0[01]000201011100101111010002020001 2011
Electrolux	11100112101001231010101020 2?010111100100110012211210 2????1001---00110100
Typhlonarke	113-00-010200121100120001101111011101110?200021111113????0000021101[12]0100
Heteronarce	111000-110100021100110102111001011101100120001112000 2????100020200110000
Narke	111000-110000121110110101110000010101100120001111[12]113111111002020011 1000
Temera	111000-110000021110120000111000010101100120 0?211211131111100002102---100
†*Titanonarke*	11??????????????????101020??000112100100020 1?11?00001???????020200012011
†*Eotorpedo*	??00002??